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SVC Reactive Power Management Using Genetic Algorithms

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***Abstract**: This paper introduces genetic algorithm-based generalized optimization as a solution to determine optimal distributed generator locations within the 10-bus network with reactive power capabilities. The improvement of both voltage stability and profile depends greatly on reactive power management. The evolutionary genetic algorithm solved the necessary reactive power planning in this research by selecting the best individuals from parent to offspring generations based on biological metaphors. The genetic algorithm adopts chromosomes exclusively so it avoids needing any initial system knowledge to begin its search process while fulfilling the determined objective functions and relevant constraints. The stabilization of system voltage requires 325.7821 MVAR reactive power injected by the Static Var Compensator (SVC) as per this research analysis.*

***Keywords**: Slack, Generator, Load, Loading Parameter, Static Var, Injection Genetic Algorithm (GA), Compensator (SVC), Reactive Power*

I. Introduction

Three major bus classifications exist in modern power systems including slack buses and generator buses as well as load buses [1]. The reference bus represents the location where technicians set voltage magnitude and phase angle measurements through its operating functions. This bus connects to the generator bus to fulfill the difference between planned system load and network losses. Swing bus is the term used for this bus because its actual power generation remains undisclosed [7]. Trustees take control of the P-V bus as their base of operations to observe both voltage phase angle and reactive power conditions along with their precise voltage levels and power outputs.

The load bus is the one where the voltage's magnitude and phase angle must be ascertained, together with the real and reactive power specifications. This bus, sometimes known as an infinite bus, maintains a constant voltage and frequency. It is undeniably true that load change scenarios are typically the cause of voltage instability in power systems. This phenomenon might quickly lead to an unstable equilibrium, which would then make it impossible for the system to function normally. Maintaining a suitable voltage level and sufficient reactive power management in the network is the best approach for appropriate compensation [2–3].

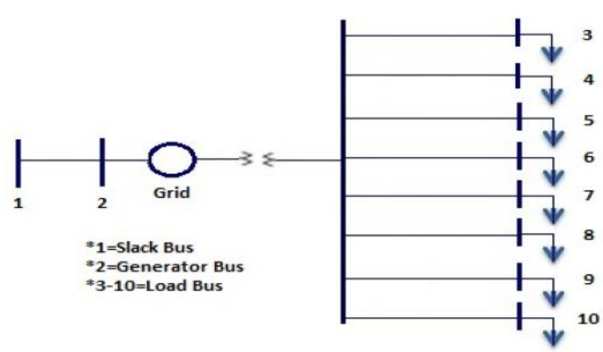

Fig 1: 10-Bus distribution network

A fresh operational methodology provides a method to accept grid system transformations. Distributing intelligence across FACTS devices such as the Static VAR Compensator (SVC) enables more adaptable operation of distribution power networks. The capability of FACTS devices to alter power distribution patterns and voltage characteristics has made them a proven solution for voltage stability enhancement [4]. An efficient reactive power dispatch becomes possible through both optimal voltages set point regulation at generator connection points and VAR setting management during power dispatch. The active power network provides capability to identify favorable VAR source placement during the planning period for efficient reactive power management [5].

Historically reactive power planning started as an optimization problem that used OPF as the ideal Power Flow problem to determine electric power system steady states in real time [6]. A Genetic method (GA) constitutes an evolutionary optimization technique that uses single objective mathematical functions to fulfil specified criteria [6]. More reactive power absorption occurs through TCR or less reactive power injection takes place through SVC when the bus voltage experiences an increase. The dynamic operation of SVC results from using thyristor devices specifically GTO and IGBT [4]. The Figure 2 demonstrates a SVC with thyristor-based control.

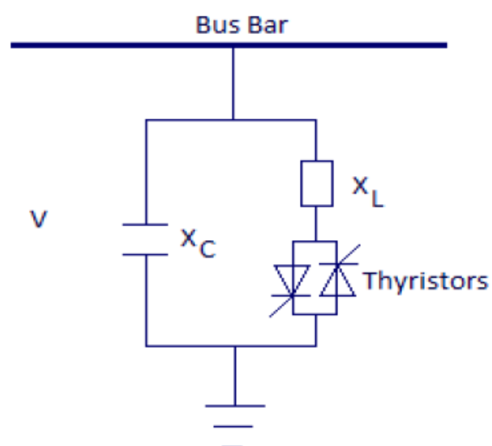

Fig 2: Static VAR compensator diagram

II. Research Method

Holland developed the Genetic method (GA) as a type of evolutionary optimization method in 1975. The algorithm operates as a meta-heuristic method for optimization which enhances candidate solutions through specific criteria to find iterative solutions to problems [3]. The normal functioning of a conventional GA requires population initialization followed by crossover and mutation and selection while the termination occurs based on termination criteria [1] as illustrated below. The solution to any problem becomes realized through a chromosome. Each gene that forms part of a chromosome serves as a variable parameter which the optimization process endeavors to enhance [2]. Fitness Evaluation and Selection assesses solution worth through the fitness function which represents the quality of each chromosome. Crossover and mutation apply to selected fit chromosomes based on their fitness value to produce new chromosomes. Through the roulette wheel selection method parents receive selection based on their fitness levels. The better the quality of chromosomes becomes the higher the probability gets for selection [3]. Every genetic algorithm performs crossover and mutation as its main operations after the selection phase. The existing chromosomes become divided by these processes which generate new ones [6-7].

During crossover all selected chromosomes unite with one another to achieve mixing through the crossover probability which enables both parents to exchange specific overlapping chromosomal segments of equal length. During crossover execution the algorithm selects a random position throughout the chromosome region and returns all genes after this point with segmentations from the two chromosome samples. After crossover each chromosome gene (except the elite chromosome) faces mutation to new codes based on a probability known as mutation probability. The assimilation of crossover and mutations results in chromosome evaluation before proceeding to the following selection cycle. The crossover and mutation parameters depend mostly on both chromosome shape and current application requirements [3–4]. This study employs Genetic Algorithms (GA) as the research methodology because

the fluctuating bus voltages stemming from variations in the load factor and the need to add unknown reactive power amounts to the system.

III. Results and Analysis

The MATLAB optimization toolbox operates the Genetic algorithm with the loading parameter to λ 0.1 per unit and the initial definition of Q as 1 per unit.

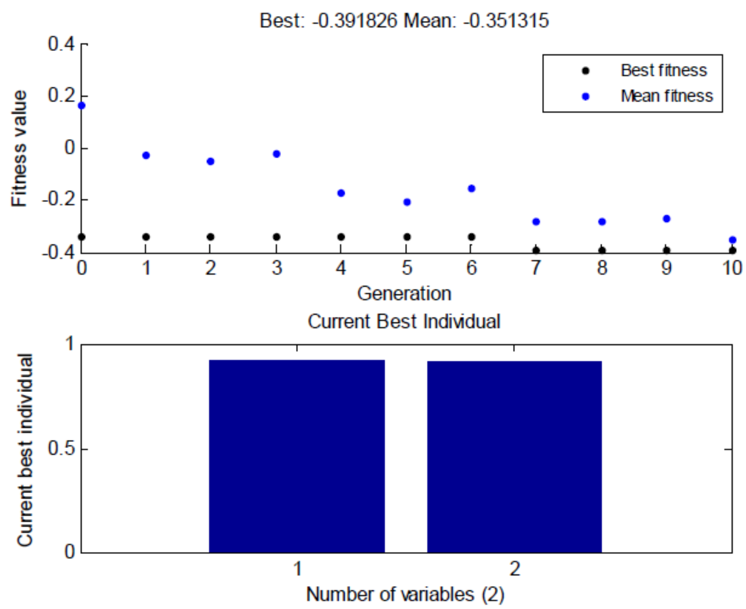

Fig 3: Solution of genetic algorithm

Local reactive power generation improves voltage quality and reduces both loss and the need for imported reactive power from the feeder. The outcome leads to enhanced voltage security in the system [5]. The available voltage at the load bus stands as a leading factor influencing the required reactive power generation amount. Specific reactive powers must be supplied through compensation devices because variations in loading parameters modify bus voltages from their expected unity per unit value as evidence shows in "Fig. 4" to maintain system stability [7].

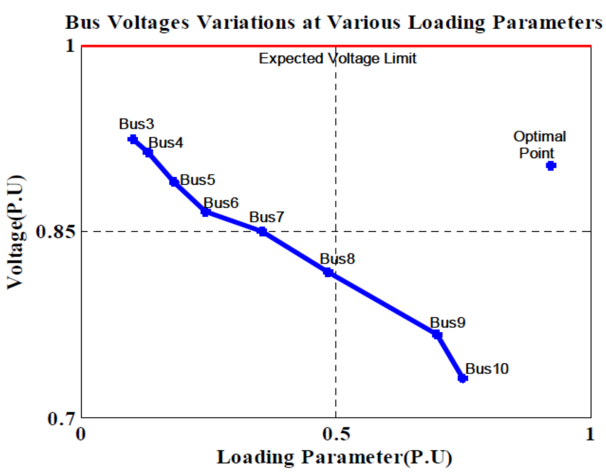

Fig 4: Available load bus voltages required to be controlled to reach the txpected limit

IV. Conclusion

The proposed method aims at stabilizing the 10-bus power system by performing effective reactive power control. The document details an evolutionary optimization process through step-by-step instructions which allows readers to grasp genetic algorithm operations. Damage to complex combinatorial optimization problems can be solved effectively by genetic algorithms because they demonstrate tremendous efficiency in reactive power planning tasks for voltage stability. The power system network with Distributed Generators (DG) has new operational possibilities delivered by this formulation which operators and planners in utility areas can utilize for planning. The proposed method demonstrates applicability for future improvements of voltage stability and DG penetration levels in distribution networks containing 100 buses. The methodology enables calculations of optimal reactive power injection levels together with the selection of DG unit locations. Genetic algorithms possess the ability to address multiple problems across several domains such as scientific, business, engineering and medical fields. These domains include production scheduling, transportation and call center routing, electrical circuit layout determination, neural network design, robot design and control, financial trading, credit evaluation, budget allocation, fraud detection together with numerous others.

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